

(12) **United States Patent**
Nalim

(10) **Patent No.:** **US 9,920,689 B2**
(45) **Date of Patent:** **Mar. 20, 2018**

(54) **HYBRID WAVE ROTOR PROPULSION SYSTEM**

USPC 60/39.45
See application file for complete search history.

(71) Applicant: **Indiana University Research and Technology Corporation**, Indianapolis, IN (US)

(56) **References Cited**

U.S. PATENT DOCUMENTS

(72) Inventor: **M. Razi Nalim**, Indianapolis, IN (US)

5,894,719 A * 4/1999 Nalim F02C 3/02
60/39.45
6,460,342 B1 * 10/2002 Nalim F02C 3/02
60/39.45
6,526,936 B2 * 3/2003 Nalim F02C 3/02
123/213
6,584,764 B2 * 7/2003 Baker B64D 27/20
137/15.1
6,845,620 B2 * 1/2005 Nalim F02C 3/02
60/39.45
8,400,005 B2 * 3/2013 Huber F01D 15/10
290/52
8,443,583 B2 * 5/2013 Nalim F02C 5/04
60/247

(73) Assignee: **Indiana University Research and Technology Corporation**, Indianapolis, IN (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 600 days.

(21) Appl. No.: **14/211,140**

(22) Filed: **Mar. 14, 2014**

(65) **Prior Publication Data**

US 2016/0194087 A1 Jul. 7, 2016

Related U.S. Application Data

(60) Provisional application No. 61/787,013, filed on Mar. 15, 2013.

(51) **Int. Cl.**
F02C 5/04 (2006.01)
F02C 3/02 (2006.01)
F02C 3/16 (2006.01)
F02C 5/11 (2006.01)

(52) **U.S. Cl.**
CPC **F02C 5/11** (2013.01); **F02C 5/04** (2013.01); **F02C 3/02** (2013.01); **F02C 3/16** (2013.01); **Y02T 50/671** (2013.01); **Y10S 903/93** (2013.01)

(58) **Field of Classification Search**
CPC F02C 3/02; F02C 3/16; F02C 5/04

(Continued)

Primary Examiner — Justin Larson

(74) *Attorney, Agent, or Firm* — Faegre Baker Daniels LLP

(57) **ABSTRACT**

A hybrid propulsion system includes a wave rotor combustion engine operating in parallel with an electrical motor-generator element. The motor-generator element is coupled to the turbine shaft to selectively drive or be driven by the turbine shaft. In one mode of operation, the motor of the motor generator element is powered by a battery to provide rotational energy to the turbine shaft. In another mode of operation, the wave rotor combustion engine drives the generator to recharge the battery. The wave rotor combustion engine may be further directly coupled to auxiliary components without a gearbox to drive the components at substantially the same speed as the turbine shaft. The turbine rotor of the combustion engine includes a plurality of chambers defined by circumferentially spaced curved vanes that improves specific fuel consumption for the engine.

19 Claims, 9 Drawing Sheets

